Effects of ocean acidification, warming and melting of sea ice on $\underline{\Omega}$ of Canada Basin surface water

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TUMSAT

Fisheries and Oceans Pêches et Océans

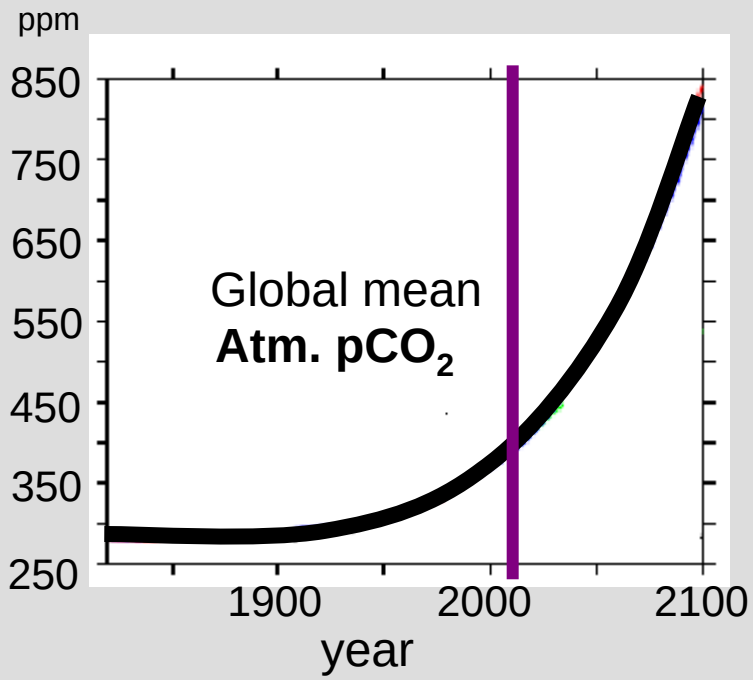
IPY 2007-2008 API

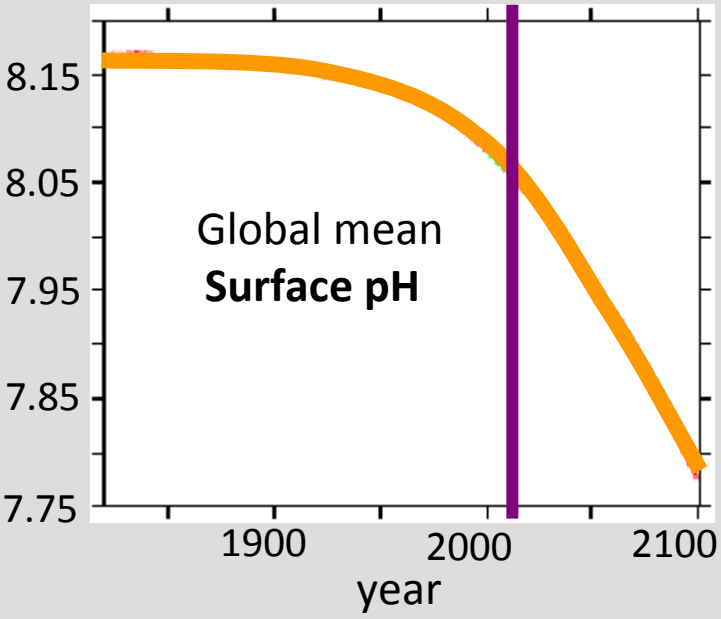
What's Ω? Why do we care?

Ω = $CaCO_3$ saturation state of seawater

Ω < 1 (undersaturated)--- $CaCO_3$ shells/skeltons are at risk of dissolution
Decease in Ω --- difficult to maintain $CaCO_3$ shells

Anthropogenic CO_2
—ocean acidification
—decrease in Ω





Anthropogenic CO_2
—ocean acidification
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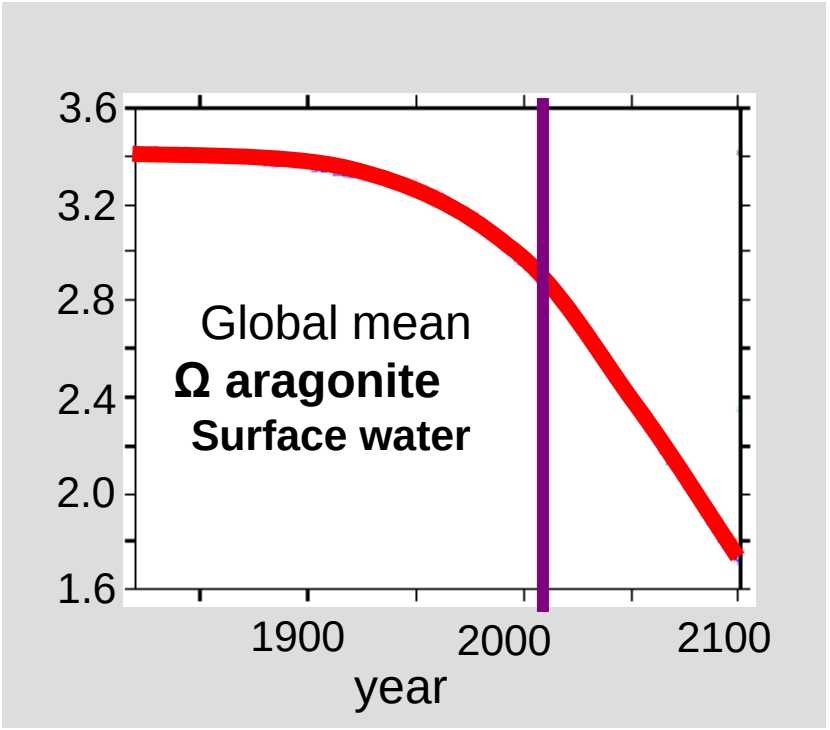
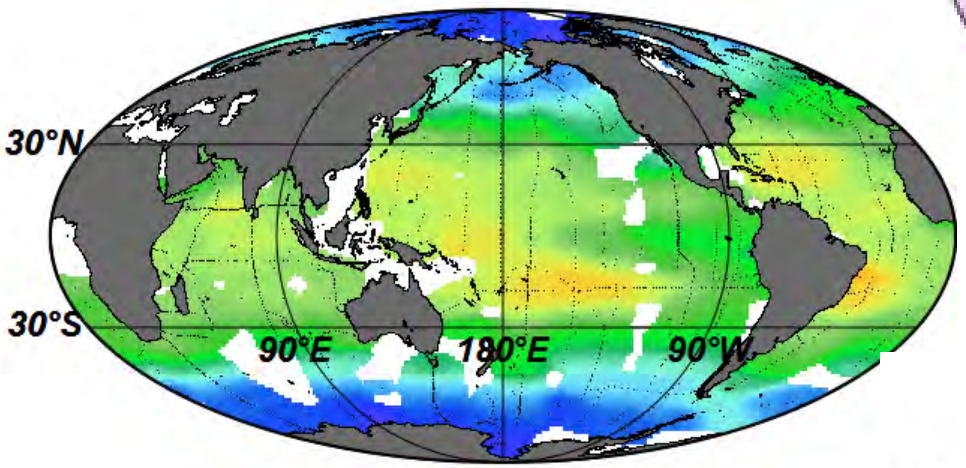
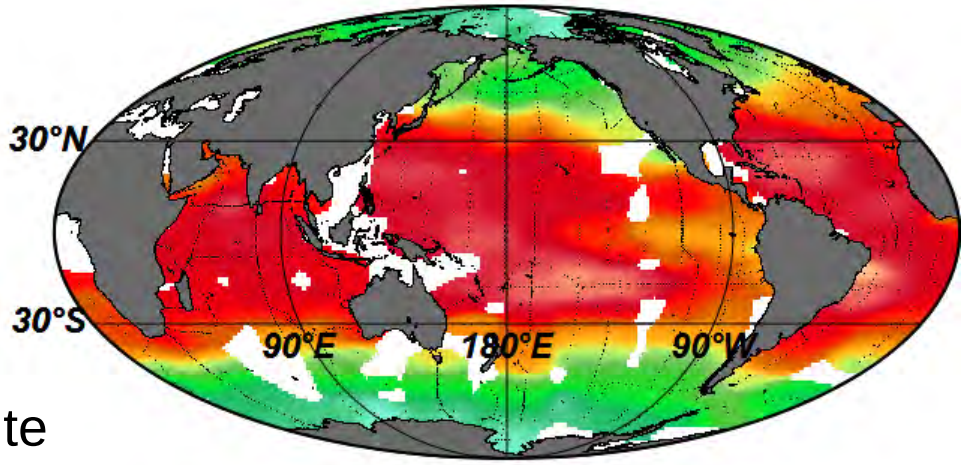


[Steinacher et al., Biogeosciences, 2009]

Ωaragnoite

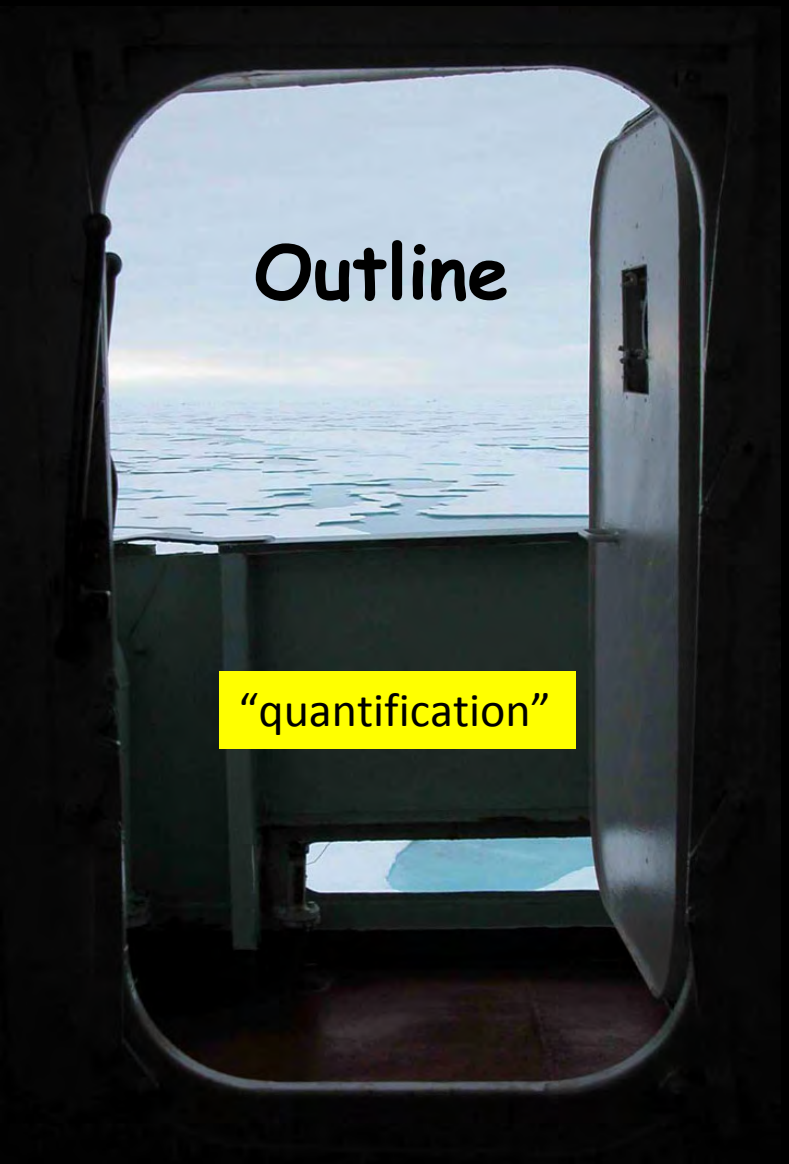


Ωcalcite



- Ωaragnoite is lower than Ωcalcite (aragonite is more soluble)
- surface Ω is low in high-latitude oceans

[90s data: CARINA+GLODAP]



Outline

"quantification"

Pan-North American view of Ω in 2007/2008

Factors controlling Ω

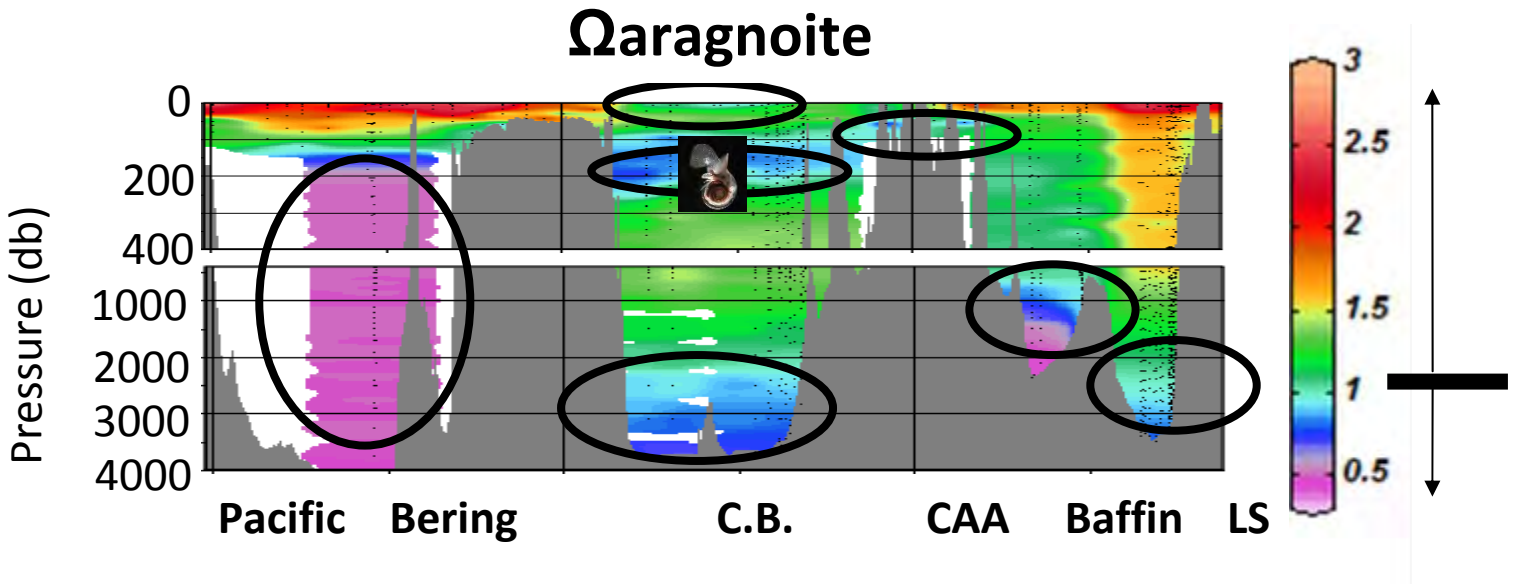
Ω in the Canada Basin surface water

How climate change affect Ω?

Compare 2008 and 1997

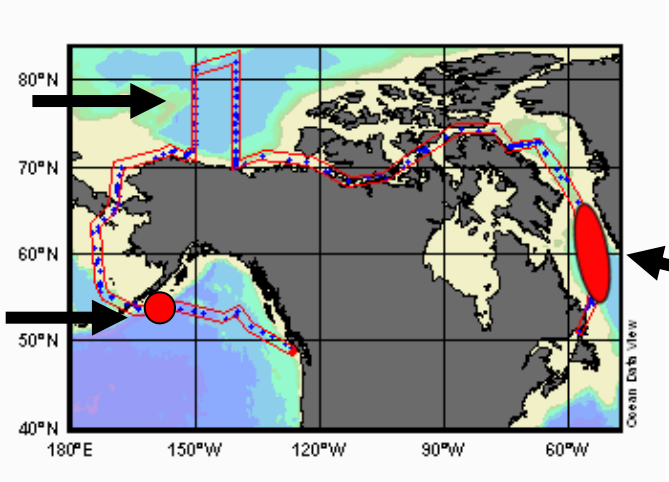
Quantify causes of recent change in Ω

2007-2008 (C3O & JOIS)



C3O/JOIS 08

C3O 08 + GLODAP



C3O 07 + GLODAP

[Yamamoto-Kawai et al., in prep]

Why Ω < 1 in these layers?

Ω is function of DIC, TA, S, T and Pr

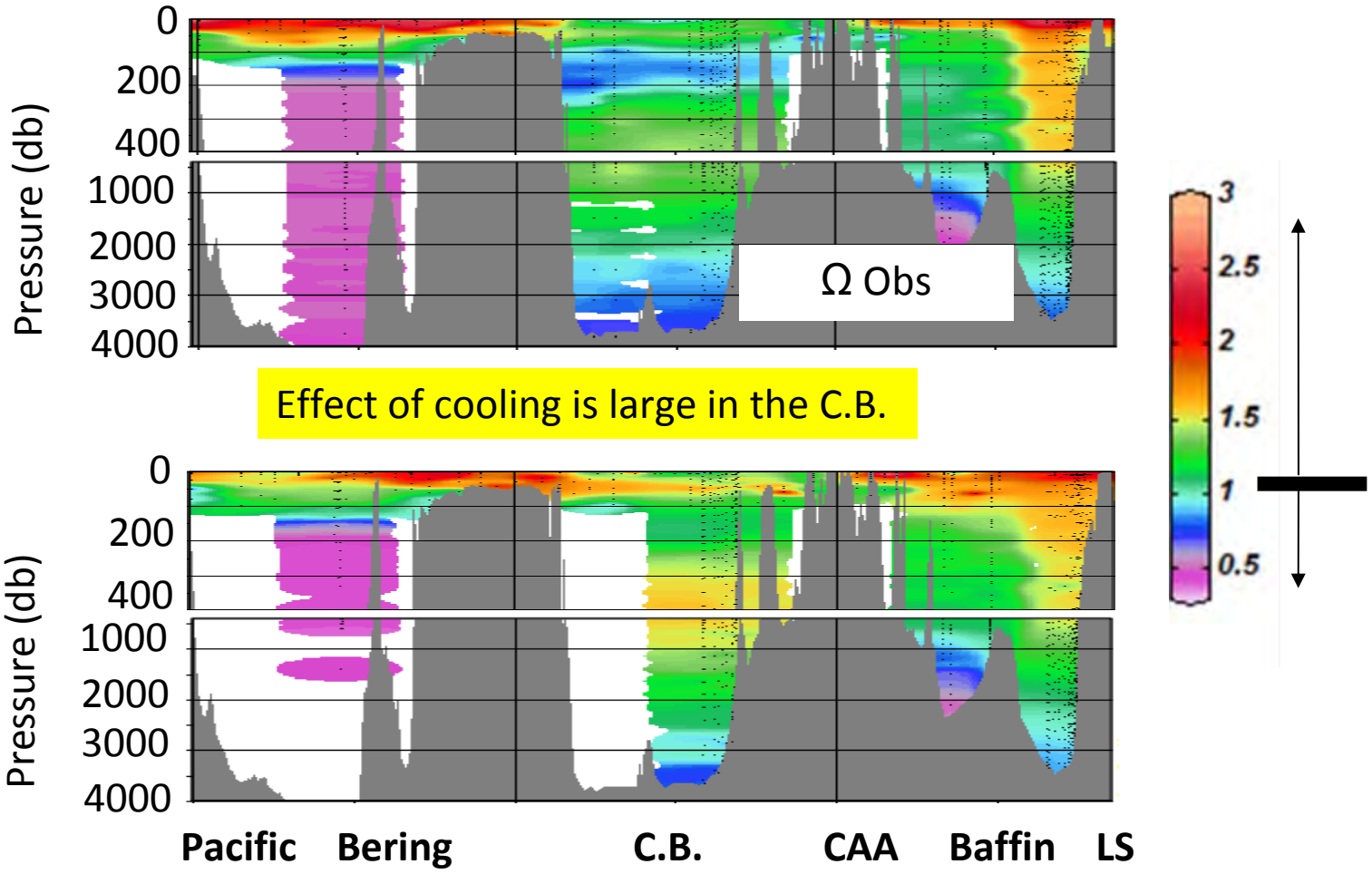
Ω decreases with

1. increasing pressure
2. cooling
3. increasing CO_2 (anthropogenic CO_2)
4. increasing CO_2 (respiration/remineralization)
5. freshwater input

How much?

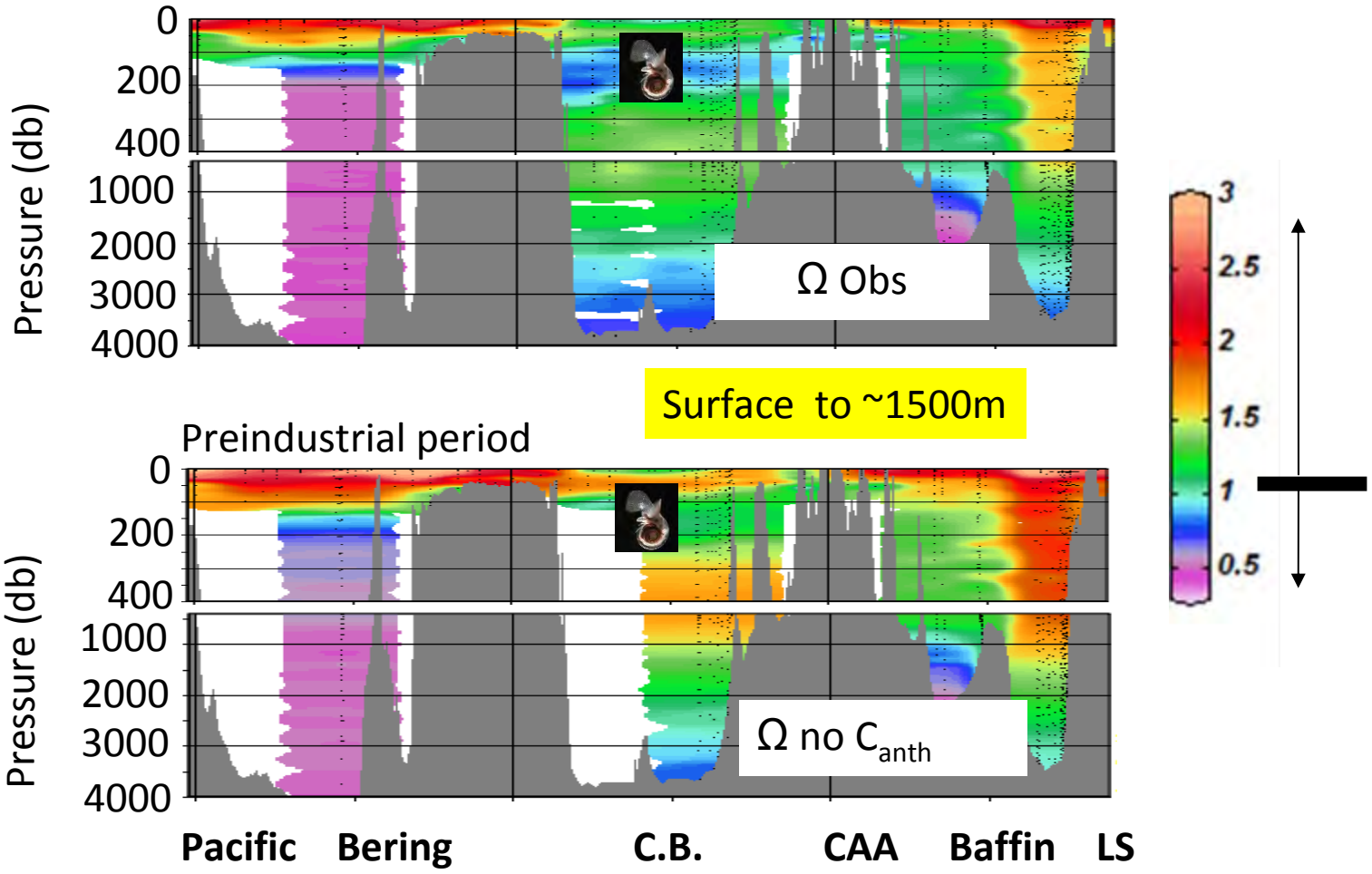
Cooling

Ω is calculated from DIC, TA, S, T and Pr



increasing CO_2 ($anthroCO_2$)

Ω is calculated from DIC, TA, S, T and Pr from pCFC12
[Sabine et al., GBC., 2002]

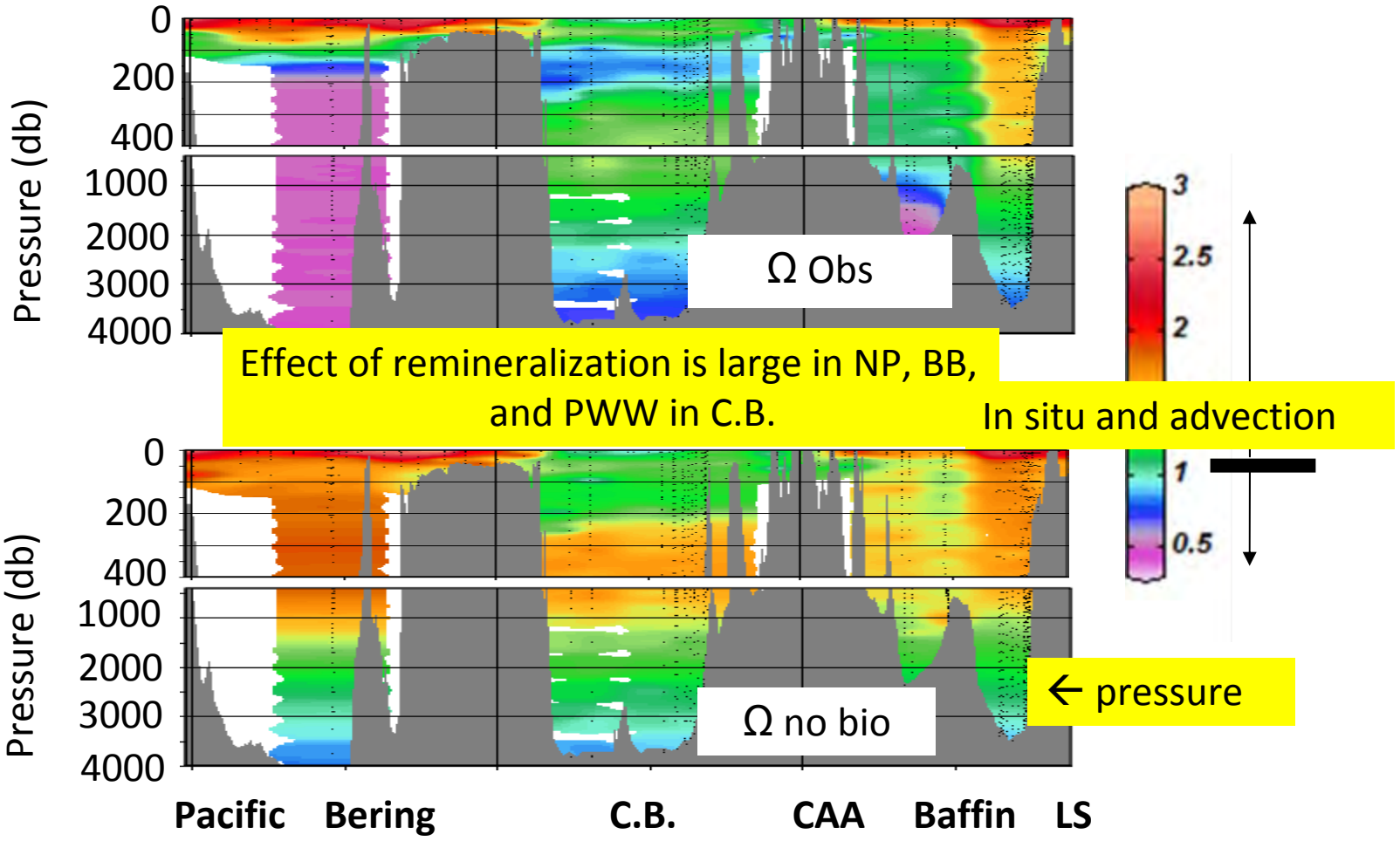


Remineralization

(+$CaCO_3$resolution+denitrification)

Ω is calculated from DIC, TA, S, T and Pr from O_2 , TA^0 and N*

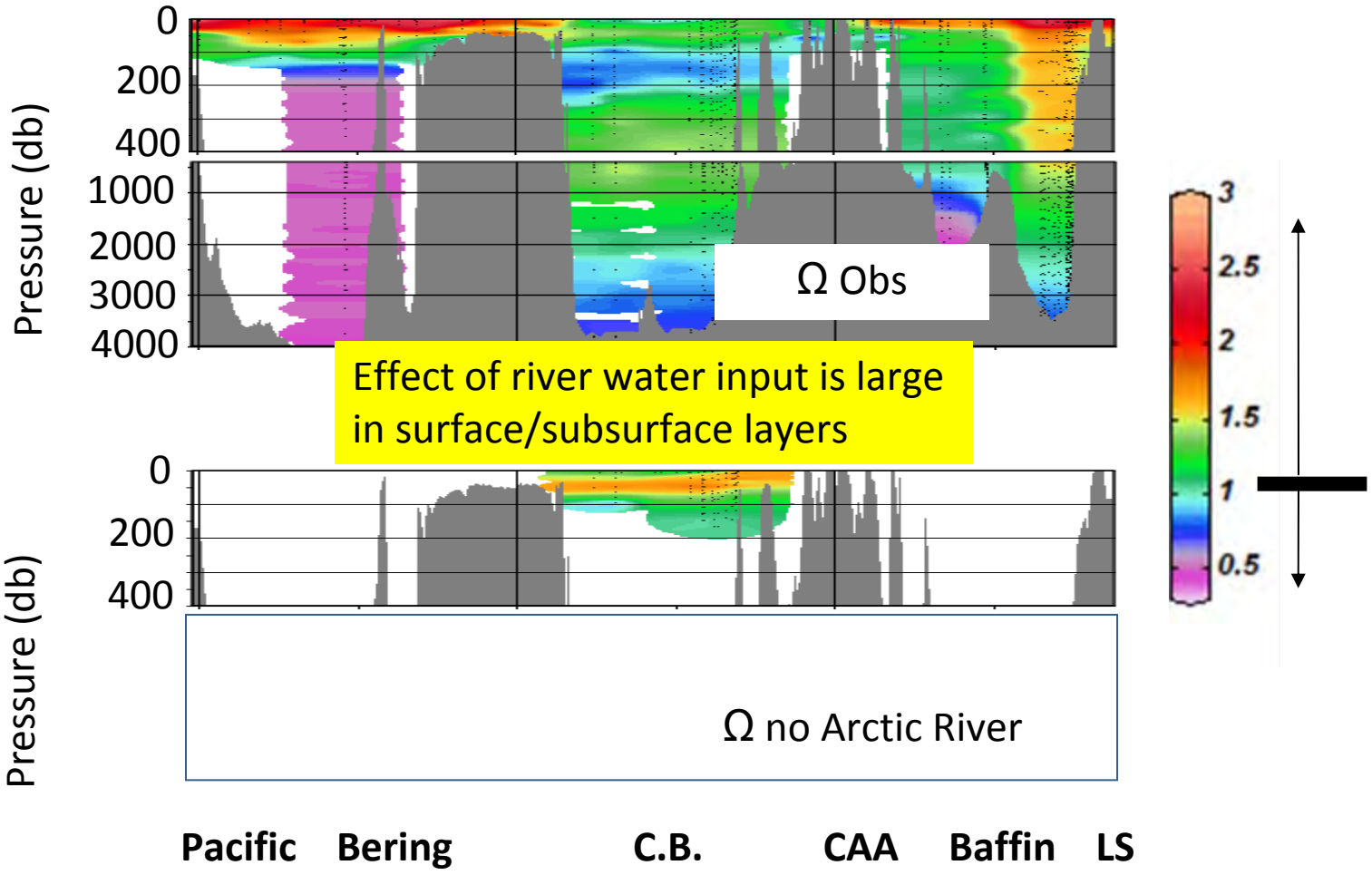
[Sabine et al., GBC., 2002]

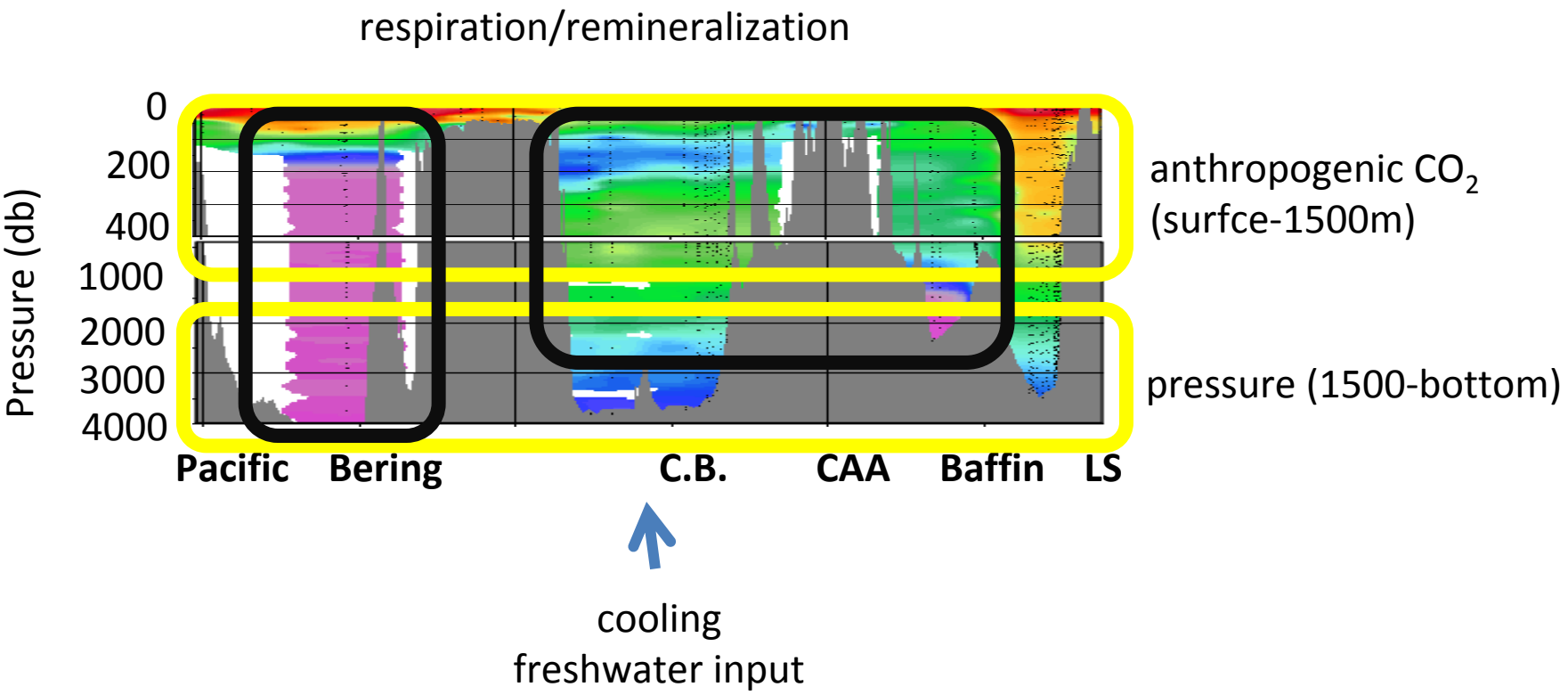


Arctic river runoff

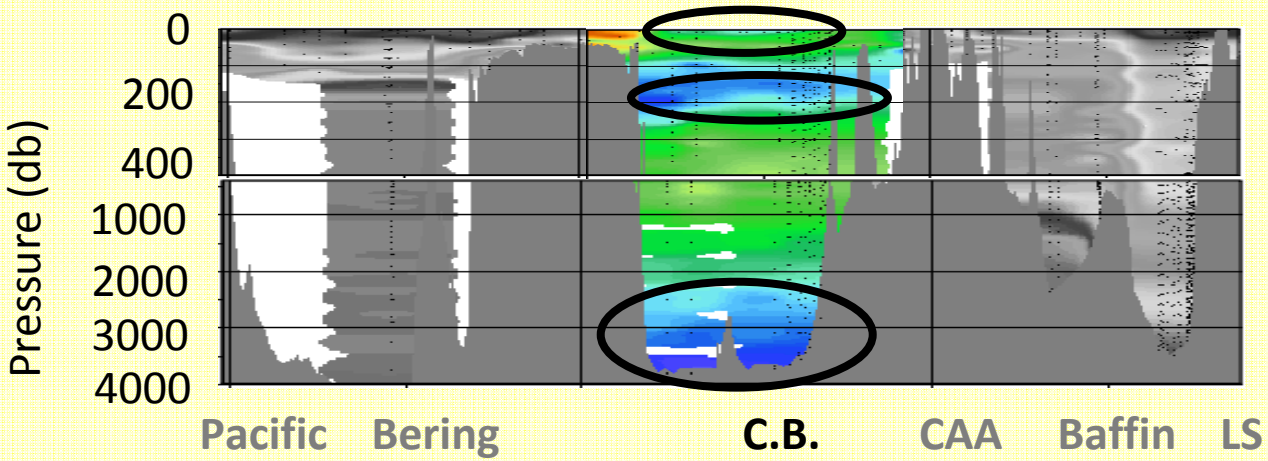
Ω is calculated from DIC, TA, S, T and Pr

from $H_2{}^{18}O$




respiration/remineralization
Pressure (db)
0
200
400
1000
2000
3000
4000
Pacific
Bering
C.B.
CAA
Baffin
LS
anthropogenic CO_2
(surfce-1500m)
pressure (1500-bottom)
cooling
freshwater input

In the Canada Basin



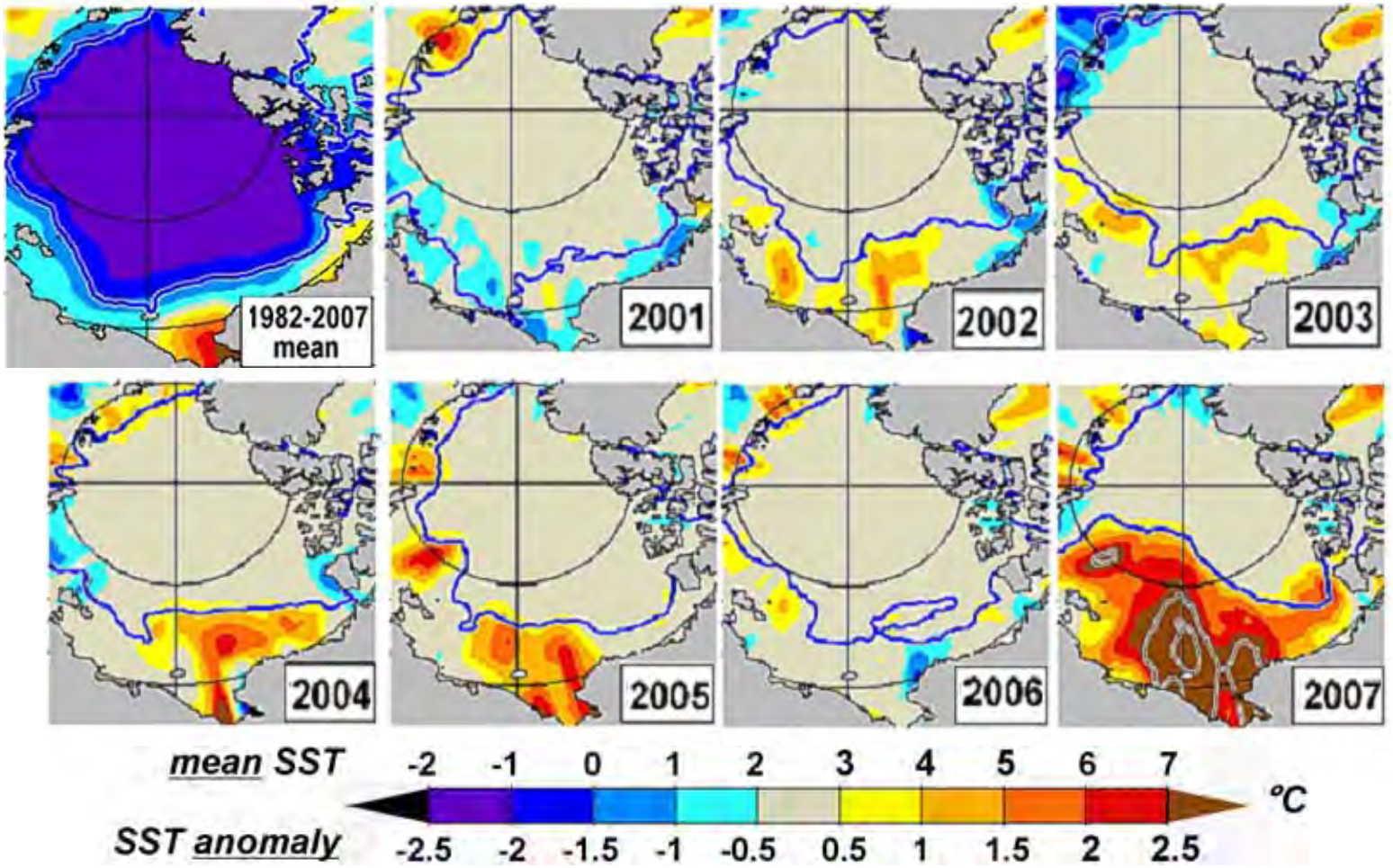
3 aragonite undersaturated layers

Bottom: **pressure**

Subsurface: **remineralization**, **freshwater input**, **anthro CO_2** , **cooling**

Surface: **freshwater input**, **anthro CO_2**, **cooling**

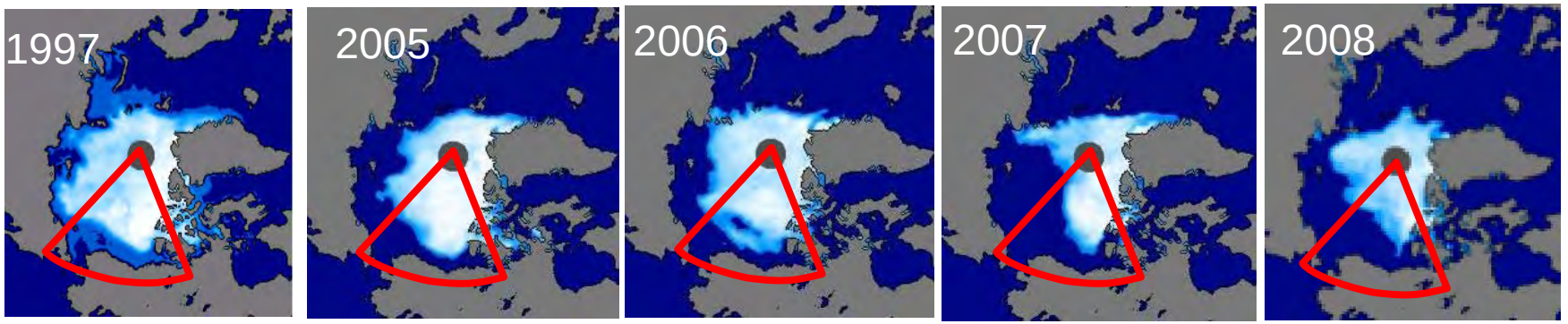
Warming



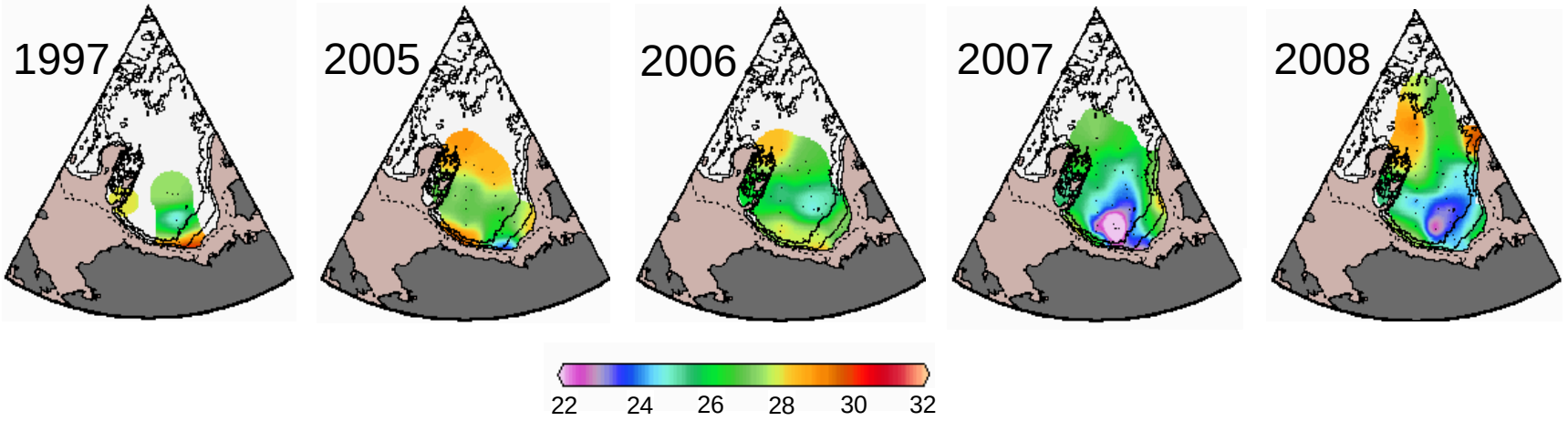
[Steele et al., 2007]

Melting of sea ice---dilution of surface seawater

Sept. sea ice extent



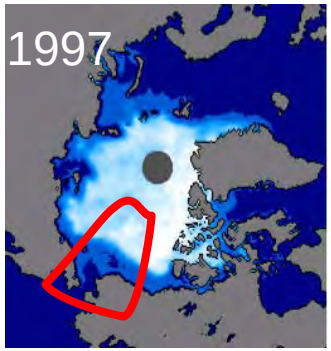
Sea surface salinity

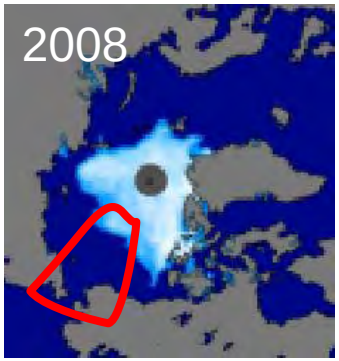


[Yamamoto-Kawai et al., 2009a]

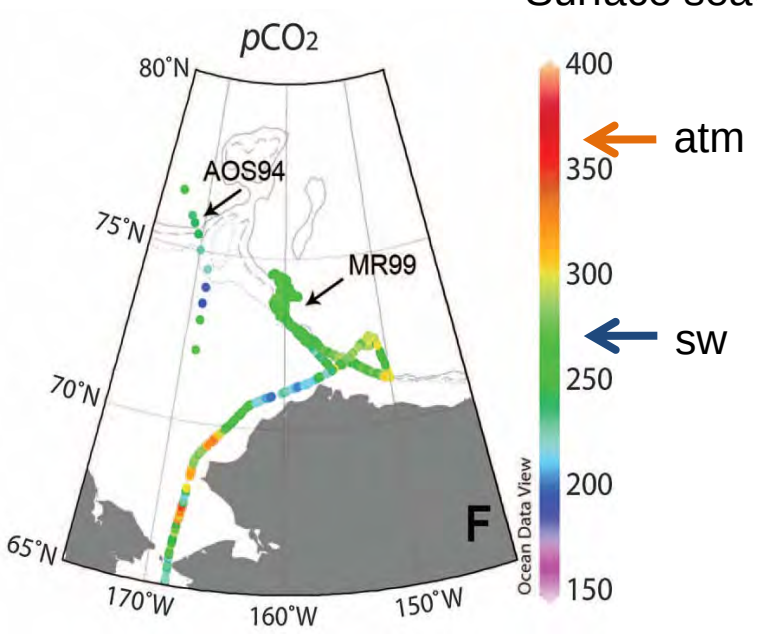
Melting of sea ice---enhancement of air-sea gas exchange

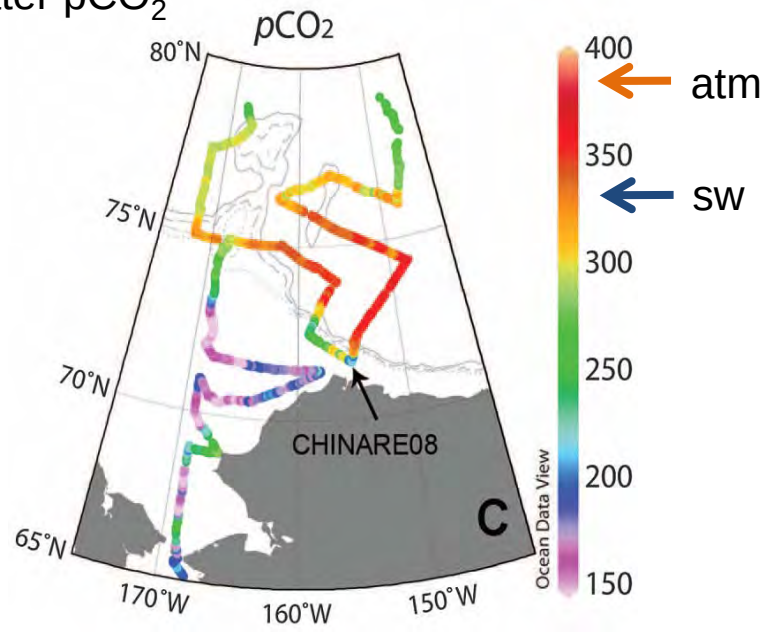
Sept. sea ice extent





Surface seawater pCO_2





[Cai et al., Science, 2010]

Ω in the C.B. surface water

Undersaturated with respect to aragonite

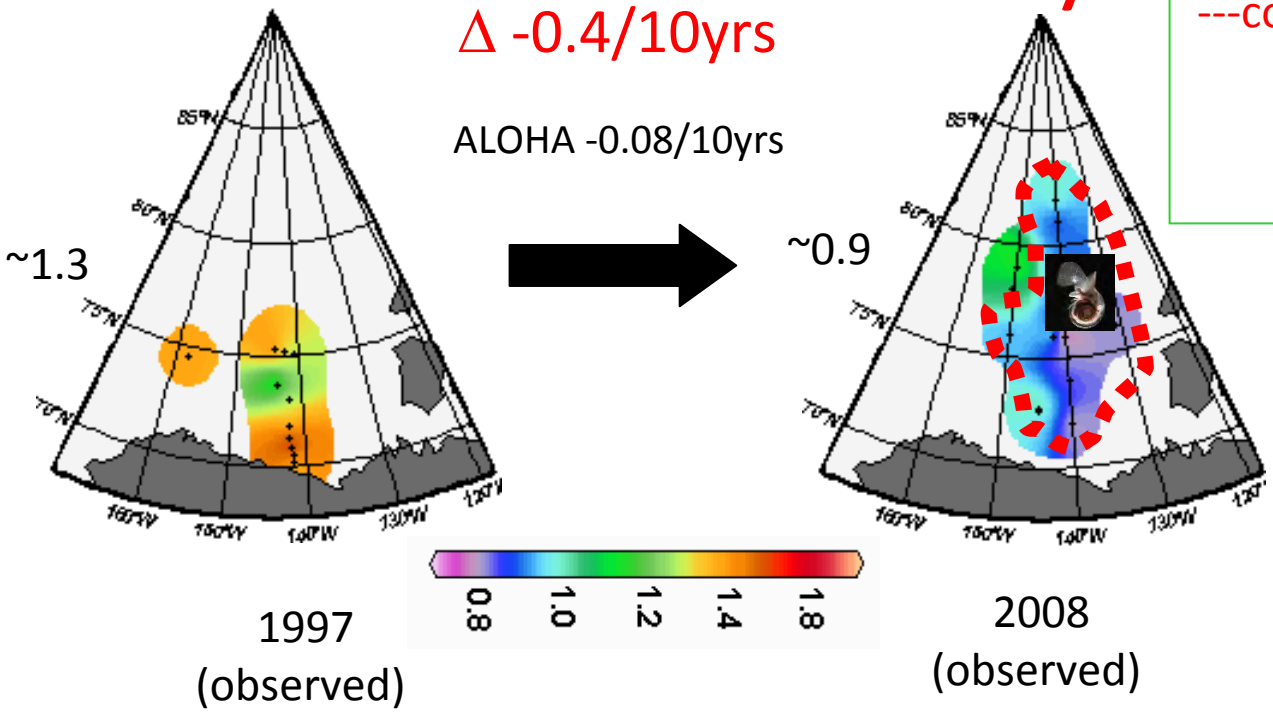
---corrosive to shells of pteropods

Ω < 1

Why?

Δ -0.4/10yrs

ALOHA -0.08/10yrs



[Yamamoto-Kawai et al., 2009b]

Factors controlling Ω of surface water in C. B.

Melting of sea ice

Enhanced air-sea gas exchange

Surface freshening

Increased atmospheric CO_2 (global ocean acidification)

Warming

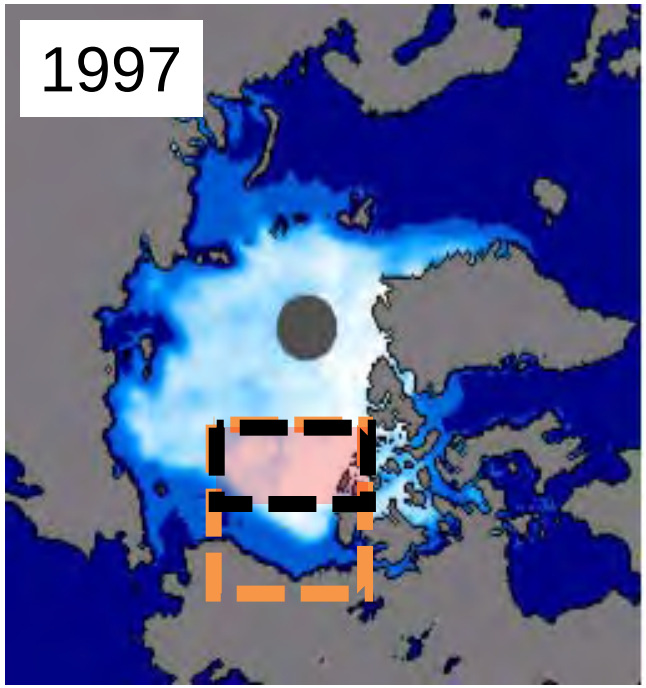
Quantify!

Ω is estimated from S, T, TA, DIC and Pr

fCO_2 in preindustrial period =280 uatm (without anthroCO2)

T^{PI} = -1.5C (without warming)

S, TA and Δc_{diseq} in preindustrial period



$\Delta Cdiseq^{PI}$ = -41 µmol/kg (without change in gas exchange)

SIM = 0

$S^{PI} = S_{obs} - \Delta SIM \cdot S_{SIM}$ (without freshening)

$TA^{PI} = TA_{obs} - \Delta SIM \cdot TA_{SIM}$ (without freshening)

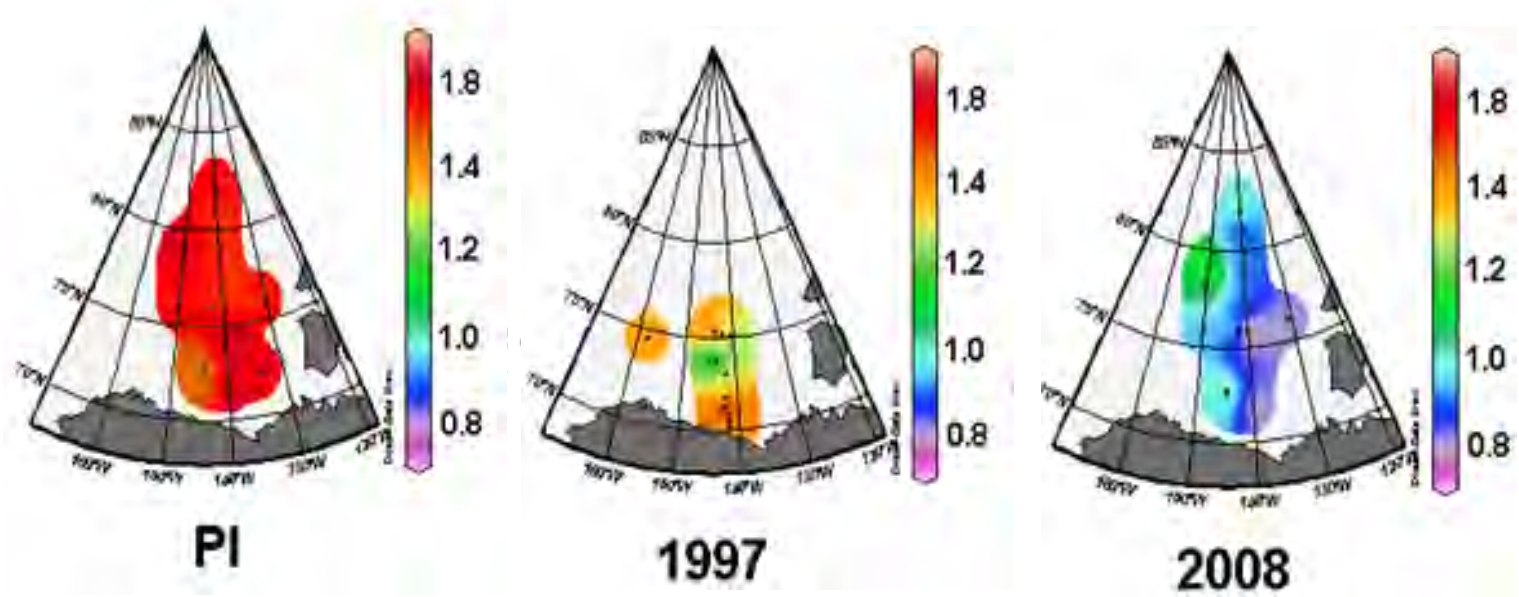
↑

SIM from $H_2{}^{18}O$

S_{SIM} 4

TA_{SIM} 441 umol/kg

Ω-aragonite



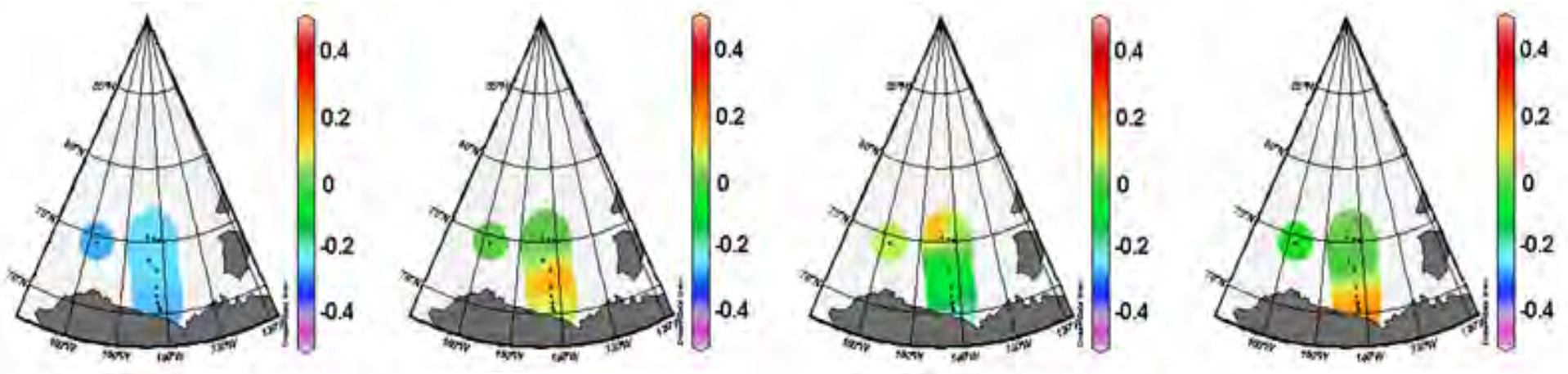
1.4 ~ 1.6 **~ 1.3** **≤ 1**

~1.5 in 1820
[Steinacher et al., 2009]

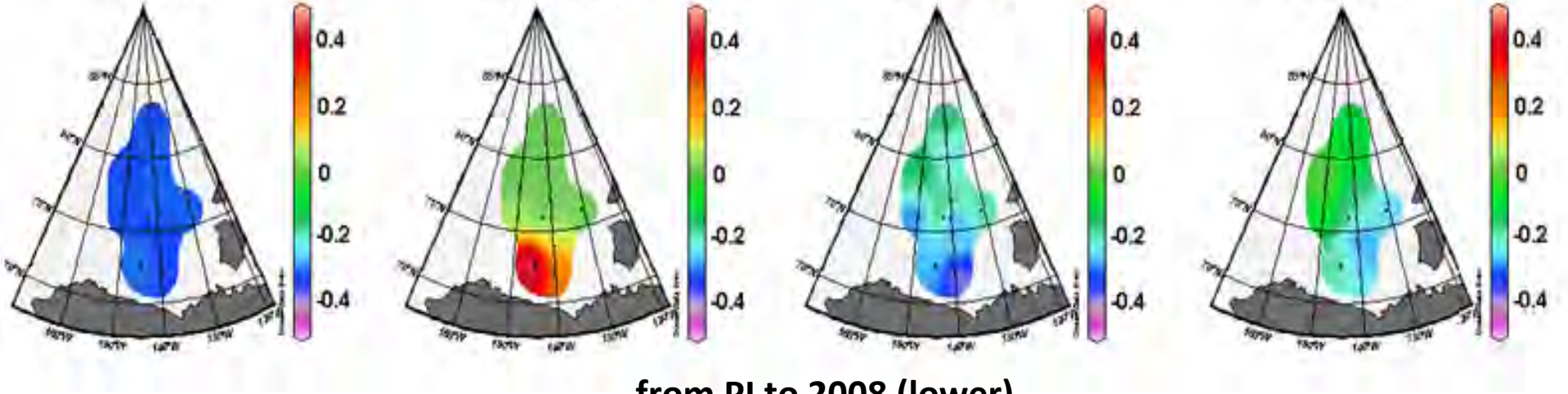
[Yamamoto-Kawai et al., 2011]

ΔΩ-aragonite

from PI to 1997 (upper)



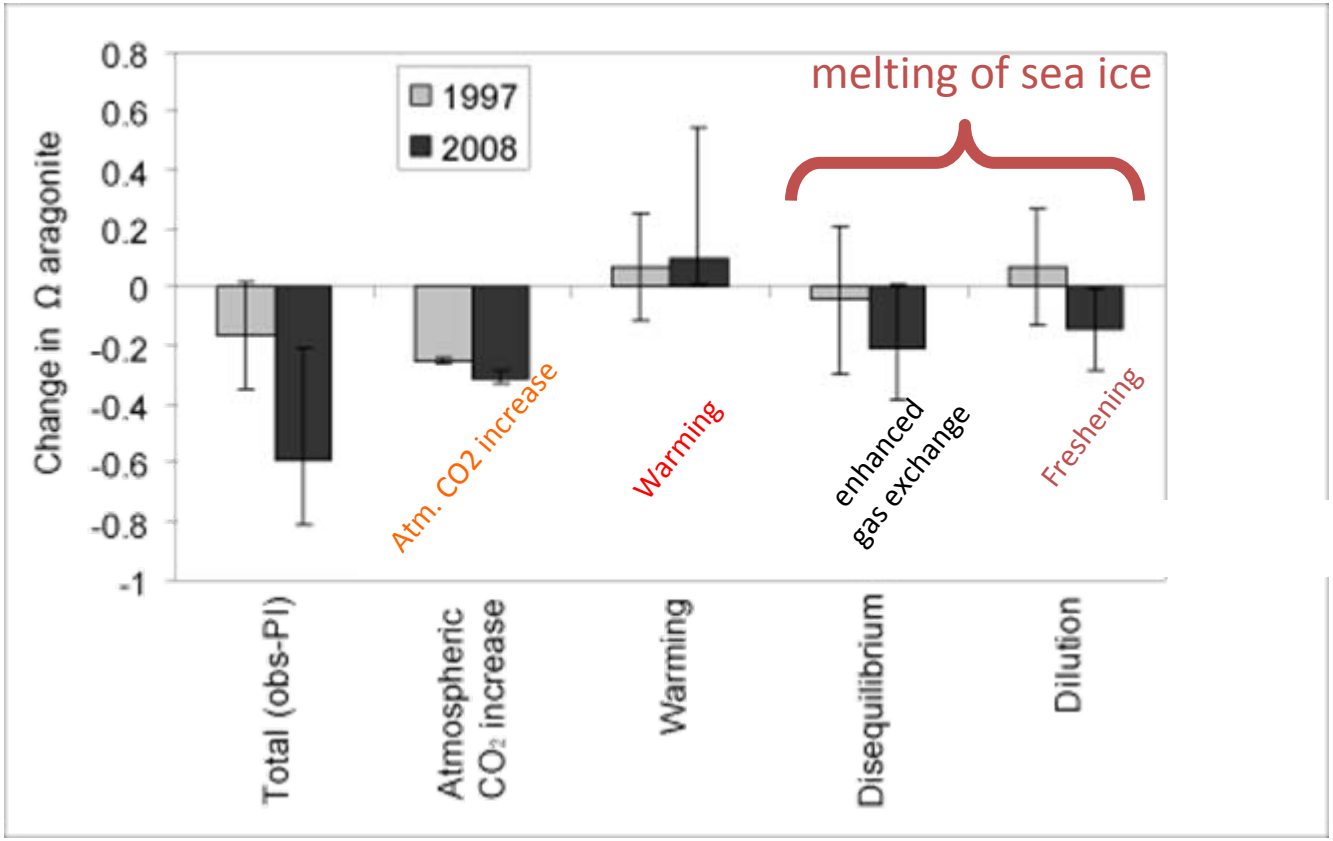
Atmospheric CO_2 | **Temperature** | **Disequilibrium** | **Freshening**



from PI to 2008 (lower)

[Yamamoto-Kawai et al., 2011]

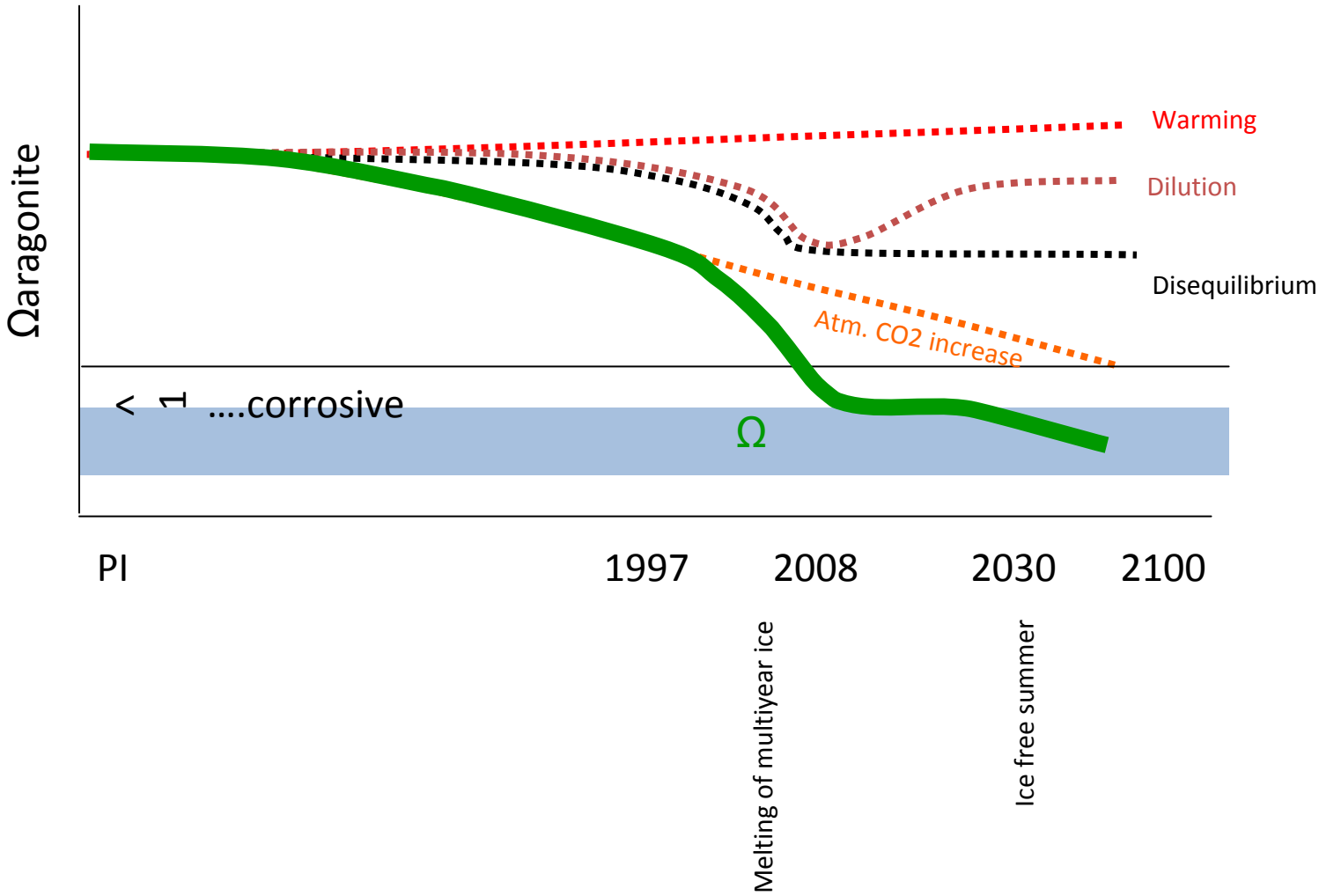
Canada Basin surface water



Mean changes in Ωaragonite in the Canada Basin surface water from preindustrial ice-covered conditions. Total change (observed – preindustrial) and changes caused by atmospheric CO2 increase, warming, air-sea

[Yamamoto-Kawai et al., 2011]

Ω in the future CB surface water ??



In the Canada Basin

There are 3 aragonite undersaturated layers

Bottom: **pressure**

Subsurface: **remineralization**, **river runoff** , **anthro CO_2**, **cooling**

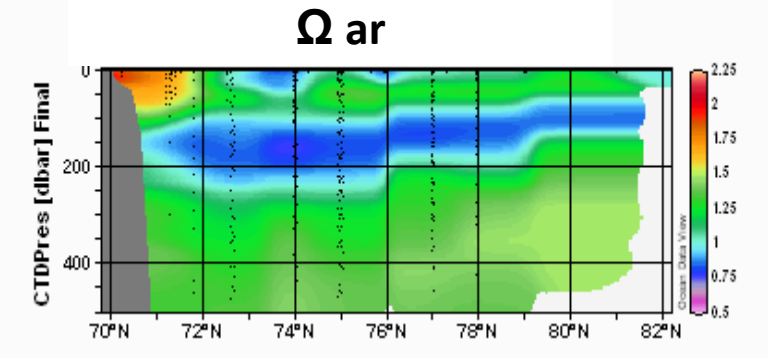
Surface: **river runoff, anthro CO_2, cooling** **in 1997**

In 2008,
+ enhanced air-sea gas exchange
+ input of sea ice meltwater
- warming

On the Shelf

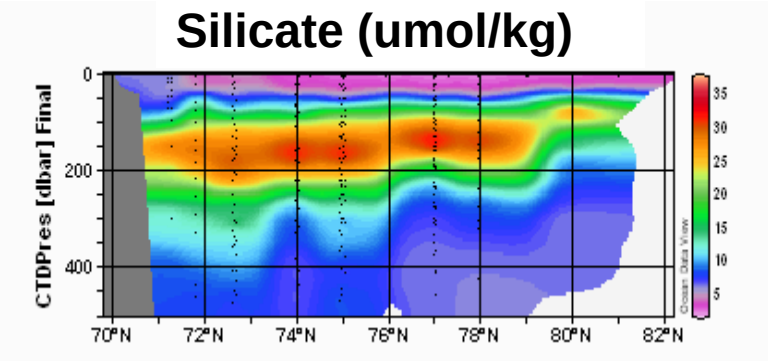
Retreat of sea ice enhances upwelling of subsurface water onto the shelf

[Carmack and Chapman, GRL, 2003]

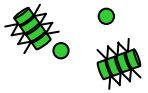


Aragonite undersaturated

→ Negative impacts on Benthos



High nutrients



→ Positive impacts on P.P.

Anthropogenic CO_2---ocean acidification

Melting of sea ice

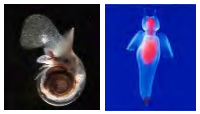
Enhancement of

air-sea gas exchange

Dilution of surface water

$\Omega < 1$

Surface water

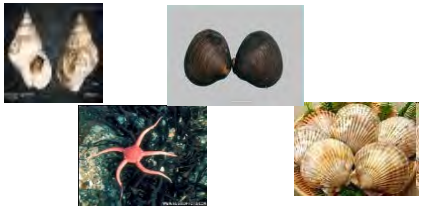


In the Basin

$\Omega < 1$

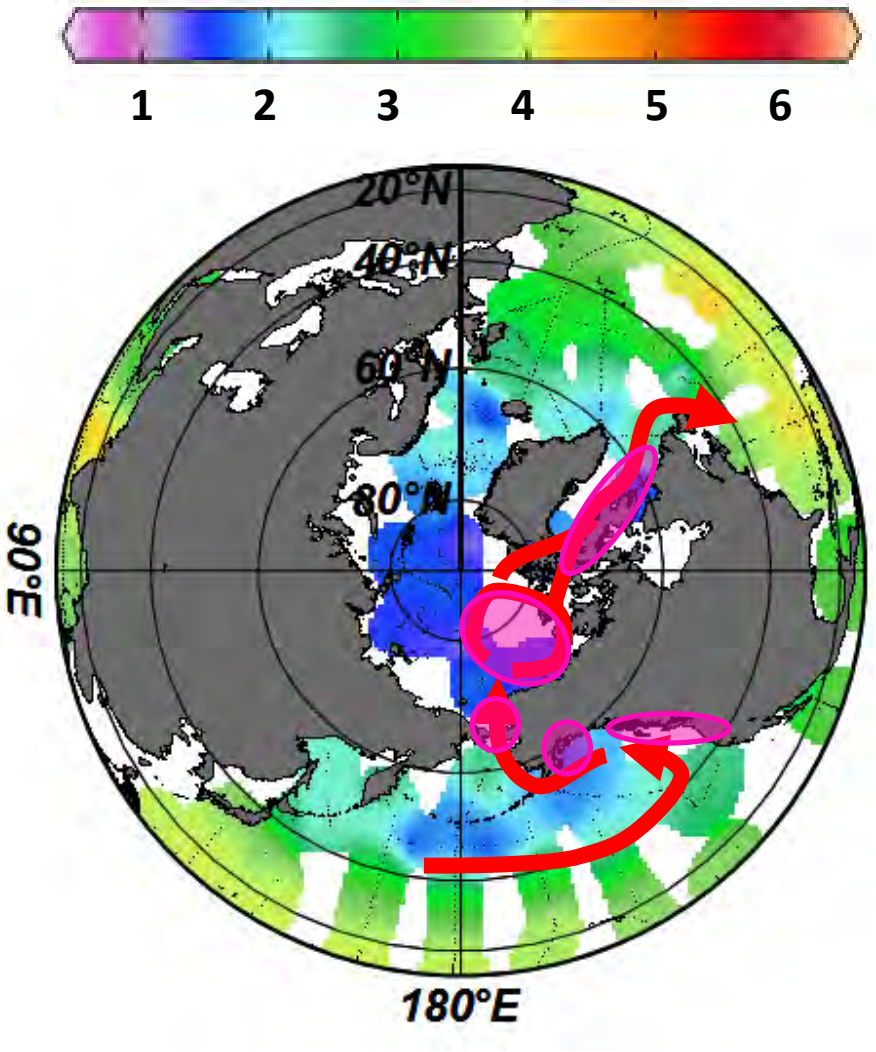
Subsurface water

Up-welling of subsurface water



On the shelf

Ωaragnoite



[90s data: CARINA+GLODAP]

Low omega water along the pathway of Arctic water [Azetsu-Scott et al., JGR, 2010]

Melting of sea ice [our study]

Undersaturated bottom & surface waters [Mathis et al., JGR, 2011]

Upwelling of acidified water [Feely et al, Science, 2008]

Thank you !